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AGASSIZ AND THE ICE AGE.

G. FREDERICK WRIGHT.

Agassiz did not claim to be the first one to see that the glaciers of the Alps formerly filled the valley of the Rhone in Switzerland and extended to the summits of the Jura Mountains. The credit of this brilliant theory he freely gave to his hospitable friend Jean de Charpentier, Director of Mines in the Canton of Vaud and living at Bex, a few miles above the head of Lake Geneva. Nor was the theory original with Charpentier. A mountaineer named Perraudin, living at the foot of the St. Bernard in Vallais, told Charpentier as early as 1815 that the large boulders along the sides of the Alpine valleys were left there by glaciers which once filled them. Fourteen years later, in 1829, an engineer named M. Venetz recalled to Charpentier the theory of Perraudin and advocated its truth. This belief of the Swiss engineer was defended in an essay read to the Swiss naturalists in 1821, but the paper remained unnoticed until Charpentier became a convert to the theory through the arguments of Venetz in 1829. The paper was not published, however, until 1833, the same year in which Charpentier's first paper on the subject was published.

But, although this paper of Charpentier presented the facts from the hands of a master, it did not convince Agassiz or many others. In 1836 Agassiz and his wife, however, accepted an invitation to spend their summer vacation with Charpentier at Bex, with the result that he returned to his home at Neuchâtel an enthusiastic advocate of the glacial theory. And well he might be, for he had himself been living among the most remarkable indications of glacial work that could anywhere be found in the world. The very soil beneath his feet was composed of the Alpine glacial grist. The whole valley was gridironed with moraines, while one of the largest known Alpine boulders, the *pierre à bot*, rested high up on the flank of the Jura Mountains, not far from Neuchâtel.

But, carefully as Charpentier had worked out his limited theory for the valley of the Rhone, he was not prepared for the far grander and more brilliant generalization which Agassiz was ready to propose. In an epoch-making address delivered at a gathering of naturalists at Neuchâtel on July 27, 1837, Agassiz propounded the theory that within a geologically recent period the whole northern hemisphere, as far down as the Mediterranean and Caspian Seas, had been covered with a vast sheet of moving glacial ice, maintaining that the glacial drift around Neuchâtel did not come from the Alps, but from the north.

Brilliant as was Agassiz's presentation of this theory, it astonished rather than convinced his hearers. Among these were Von Buch and Elie de Beaumont, two of the most influential geologists of the time, both of whom were fairly horrified by the seeming extravagance of the theory. Agassiz was then but thirty years old, and had strong hopes of being promoted to a professorship in some of the larger universities of Europe. The indorsement he had received from Cuvier and Humboldt amply justified him in such expectations. But whatever the prospects had been before, they were scattered to the winds by this address with its unfavorable effect on the minds of the influential naturalists who were present.

Even the warmest admirers of Agassiz would not contend that all portions of his theory as first presented were correct. He was mistaken in supposing that the ice which covered Switzerland had any of it come from the north. Charpentier was right in holding that the Alps constituted the centre of the whole glacial movement in that part of Europe. But Agassiz was correct in his belief that there had been a general refrigeration of the northern hemisphere which had profoundly changed both the plants and the animals of the whole region. The theory as propounded by Agassiz and afterwards verified by him is scarcely less grand, impressive, and revolutionary than was that of the Copernican system of astronomy, while the work of verifying, defending, and giving currency to the theory demanded scarcely less genius than that of its origination. But for this task also he was fully competent.

In 1838 he began that careful study of the Alpine glaciers which brought out most of the facts which have since convinced the world of the reality of the glacial period. With a party of six he ascended the valley of the Aar to the Grimsel Pass, and, upon his return after ten days, started at once for Chamounix, where the party was gone a week. With the additional facts gathered in these trips, Agassiz attended the meeting of the Geological Society of France at Porrentrui (Sept. 5, 1838), where he was more successful than the year before in convincing the sceptical of the truth of his theory. In August, 1839, Agassiz resumed his glacial studies, and, taking with him a number of eminent geologists, visited Monte Rosa and the Matterhorn, when, after studying the Gorner Glacier, he made a visit to the Aletsch Glacier and the Merjelen Lake, and thence went on to the Glacier of the Rhone, subsequently visiting again the Grimsel Pass and the Glacier of the Aar. As a result of this excursion, the most determined opponents of the glacial theory who accompanied him became convinced.

The characteristic respect which Agassiz paid to ordinary observers appears in a conversation of his with his guide to the Gorner Glacier. "Seeing a vertical wall of serpentine finely polished, he asked the guide to what that phenomenon was due. The guide, who had not the smallest interest in the glacial question, answered with great *naïveté* that in the country (*le pays*) everybody thought that it was made by the glacier, adding: 'It is true that no inhabitant of the village remembers to have seen the glacier in this place, but it was there formerly, for it is always in this way that the glaciers wear away the rocks.'"[1]

Upon this excursion Agassiz was taken by his guide to see the cabin upon the Glacier of the Aar which had been built and occupied by the monk Hugi of Soleure in 1827. Ten years later it was found that the cabin had moved downward with the surface of the glacier a distance of 2028 feet, or about 200 feet per annum. Agassiz resolved to return the next year and either reoccupy this cabin or build one for himself.

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[1] *Life, Letters and Works of Louis Agassiz*, by Jules Marcou. New York, Macmillan, 1896. Vol. i, p. 145.

Meanwhile his observations had been already so complete that he felt himself justified in writing an extended work setting forth his glacial theories. This volume, entitled *Études sur les Glaciers*, was published in September, 1840, and was accompanied with eighteen beautiful plates. In the treatise explicit reference is made to the prior discoveries of Venetz and Charpentier, the work, indeed, being dedicated to them. Nevertheless, considerable ill feeling arose on account of this priority of publication.

In August, 1840, Agassiz returned to Hugi's cabin on the Glacier of the Aar with the intention of occupying it, but found that it had disappeared, there being only some of the *débris* remaining two hundred feet below the position occupied by it the year before. Whereupon Agassiz proceeded to build for himself a shelter under the projecting side of a huge boulder which was a prominent object upon a medial moraine. With this as the centre, he, with numerous colaborers, carried on for three successive summers those minute and careful observations upon glaciers which have been the basis of all subsequent speculation. In order to study the interior construction, they made deep borings into the ice, and on one occasion Agassiz was let down by a rope one hundred and twenty feet into a crevasse, while on another he spent a lonely night on the Siedehlhorn. To determine the rate of motion, he set a row of stakes across the glacier and took observations to determine their changes of position during an extended period.

While this work was in progress, Agassiz was visited by James D. Forbes, an English engineer of eminence, who spent some weeks with the party on the Aar Glacier in 1841. A year later Forbes returned to Switzerland and with his accurate mathematical instruments made observations upon the Mer de Glace sufficient to determine accurately the laws of its motion. A report of this was published by Forbes in the Edinburgh *New Philosophical Journal* in its issue for October, 1842. The report was dated, however, July 4, 1842. Meanwhile Agassiz had published the results of his observations upon the movements of the Aar Glacier in the *Comptes Rendus* of the 29th of August, 1842, two months before the publication of Forbes's letter. But Agassiz's report was dated twenty-seven days later than that of Forbes. Naturally enough, this complicated condition of things led to a spirited discussion as to priority of discovery. But there can be no question of Agassiz's originality in the matter. Without any reference to Forbes, he had, by his slow process of observing his stakes during a succession of years, determined that the central portion of the glacier moved faster than the portion near the side; for in 1842 the stakes in the middle of the glacier, set the year before, were one hundred feet farther down than those near the sides. On the other hand, Forbes has never been able to free himself from the suspicion of having unfairly availed himself of Agassiz's generous hospitality to copy his method and put it into execution at the earliest opportunity.

Having thus convinced the Swiss geologists that their own country had once been completely enveloped in glacial ice, the still more difficult task remained of extending the theory to other countries. The first opportunity for such extended observation offered itself during the autumn of 1840, when Agassiz attended the meeting of the British Association at Glasgow, when, during numerous excursions taken over the north of England, Scotland, and Ireland in company with Buckland and Lyell, he established the fact that all those regions had been deeply enveloped in glacial ice. Murchison, however, with many other eminent British geologists, continued to doubt the theory and to endeavor to explain the scratches on the rocks, the transportation of boulders, and the accumulation of moraines on the iceberg theory. During this visit Agassiz's quick eye saw the resemblance between the parallel roads of Glen Roy and such terraces as would naturally form around a glacial lake such as he had studied in the Merjelen Sea, on the border of the Aletsch Glacier.

Agassiz's last visit to the Glacier of the Aar was at the beginning of 1845, when he transferred his observations to Daniel Dollfus-Ausset, who faithfully continued them until 1861.

Agassiz, meanwhile, was approaching the great crisis of his life. Business failures broke up his work at Neuchâtel, and he came to America in 1846 to give a course of Lowell Institute Lectures in Boston, which he had been invited to do upon the recommendation of Sir Charles Lyell. With imperfect knowledge of English he succeeded in holding immense audiences on the general subject of "The Plan of the Creation, especially in the Animal Kingdom." The course was a marked success, notwithstanding his unfamiliarity with the English language. But it was followed by one more to his liking, given in the French language, upon "Les Glaciers et l'Epoque Glaciaire." From this time on the incidental observations of the great naturalist upon glacial phenomena became a most important part both of his own work and of the general literature of the subject.

In 1848 Agassiz made his celebrated excursion to Lake Superior in company with a small party of Harvard College students and Boston gentlemen. In a remarkable volume, now difficult to obtain, which resulted from this expedition, there is to be found a great wealth of glacial observations made at every stage of the journey. It was indeed a grand verification of his original theory. In 1864 Agassiz made an extended excursion in Maine, and brought back an immense amount of material in support of his glacial theory. The *Atlantic Monthly*, in an article entitled "Glacial Phenomena of Maine," contains his report upon the moraines and eskers and kames which there so reminded him of similar phenomena in his native country. The abundant later literature upon the subject is little more than a commentary upon these original observations of the great promulgator of the glacial theory.

In 1865 and 1866 Agassiz made extended explorations in Brazil mainly in the interests of biological science. In a side trip, however, which he made amid great difficulties in the rainy season in the Province of Ceara, 4° south of the equator, he thought he discovered numerous medial, lateral, and frontal moraines at an elevation of only eight hundred feet above the sea. But it is supposed by later observers that he was misled by the resemblance to glacial phenomena which often arises in connection with the slow disintegration of granitic masses in which the residuary boulders sometimes have a close resemblance to those which are distributed by glacial transportation. But in a later tour, in 1871 and 1872, around South America and through the Strait of Magellan, his glacial observations were very extended and of the highest value.

Thus, when the end came, Agassiz had lived, not only to see his brilliant theory generally accepted in its main features, but himself to verify it in both hemispheres and in three of the great continental masses. When we remember that glacial studies were merely his avocation, occupying but the spare hours of one whose life was overcrowded with other work, our admiration both for the genius and the industry of this great man can find no adequate expression. His incidental work was really greater than that which is accomplished by the main efforts of most men. It is fitting that a glacial boulder from his native land should mark his burial-place in the cemetery at Mt. Auburn, where his body lies amid the glacial accumulations which he himself had made so luminous and so instructive.

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